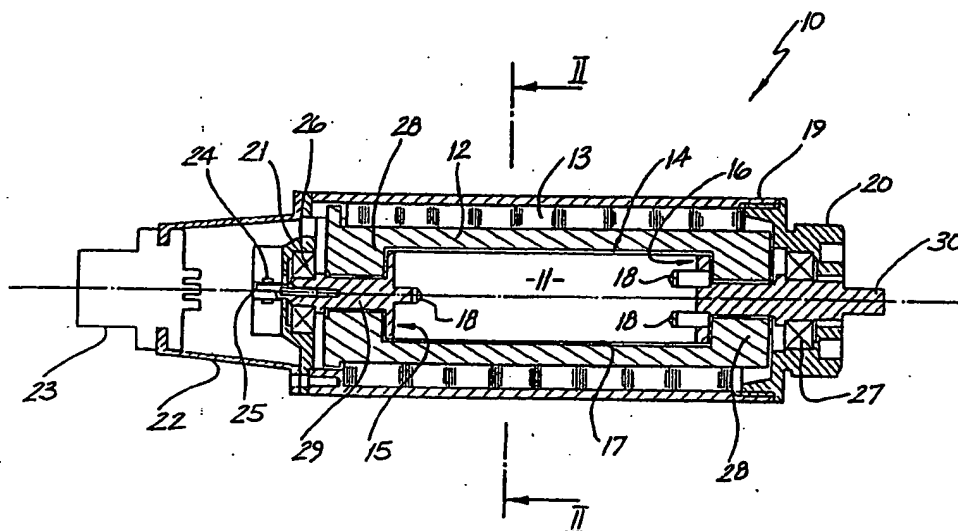




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H02K 3/47	A1	(11) International Publication Number: WO 93/26075 (43) International Publication Date: 23 December 1993 (23.12.93)
<p>(21) International Application Number: PCT/AU93/00274</p> <p>(22) International Filing Date: 10 June 1993 (10.06.93)</p> <p>(30) Priority data: PL 2885 11 June 1992 (11.06.92) AU</p> <p>(71) Applicants (for all designated States except US): UNIVERSITY OF TECHNOLOGY, SYDNEY [AU/AU]; 15-73 Broadway, Broadway, NSW 2007 (AU). COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION [AU/AU]; Limestone Avenue, Campbell, ACT 2601 (AU).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): DUNLOP, John, Burton [AU/AU]; 27 Monteith Street, Turrumurra, NSW 2074 (AU). RAMSDEN, Victor, Stuart [AU/AU]; 55 Chisholm Avenue, Clareville, NSW 2107 (AU).</p>		<p>(74) Agent: SPRUSON & FERGUSON; G.P.O. Box 3898, Sydney, NSW 2001 (AU).</p> <p>(81) Designated States: AU, CA, JP, KR, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</p> <p>Published With international search report.</p>

(54) Title: AN ELECTRIC MOTOR AND METHOD OF MANUFACTURE



(57) Abstract

An electric motor (10, 90) is disclosed having a rotor (11) which has a solid cylindrical rotor body (17) formed of a magnet of high permanent magnetism, such as is obtained from rare earth materials. Configured about the rotor (11), and within a slotless armature core (13) formed of annular laminations, is a slotless non-skewed armature winding (12, 91). The winding (12) can be configured to have ends (28) that overlap and enclose ends (15, 16) of the rotor body (17). Alternatively the winding (191) can have ends (91, 92) that overlap and enclose respective ends of the armature core (13).

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FR	France	MR	Mauritania
AU	Australia	GA	Gabon	MW	Malawi
BB	Barbados	GB	United Kingdom	NL	Netherlands
BE	Belgium	GN	Guinea	NO	Norway
BF	Burkina Faso	GR	Greece	NZ	New Zealand
BG	Bulgaria	HU	Hungary	PL	Poland
BJ	Benin	IE	Ireland	PT	Portugal
BR	Brazil	IT	Italy	RO	Romania
CA	Canada	JP	Japan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	KZ	Kazakhstan	SK	Slovak Republic
CI	Côte d'Ivoire	LI	Liechtenstein	SN	Senegal
CM	Cameroon	LK	Sri Lanka	SU	Soviet Union
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	MC	Monaco	TG	Togo
DE	Germany	MD	Madagascar	UA	Ukraine
DK	Denmark	ML	Mali	US	United States of America
ES	Spain	MN	Mongolia	VN	Viet Nam
FI	Finland				

AN ELECTRIC MOTOR AND METHOD OF MANUFACTUREField of Invention

The present invention relates to an electric motor and method of manufacture and in particular, discloses a configuration which affords
5 high power and high efficiency for comparatively small size and low rotational inertia.

Background to the Invention

In many electric motor applications, it is desirable to provide high power, high efficiency whilst providing small size and maintaining
10 low temperature rises. Typical small motors have been based on the standard DC motor which generally comprises a stator formed out of permanent magnets, and a rotor having a winding energized through brush contacts. However, such a configuration is relatively inefficient, and requires significant maintenance through the replacement of the brushes,
15 particularly when the motor is used under high load.

For high performance applications, the standard DC motor has been replaced by the so-called "brushless DC motor" which, in spite of it being energized by alternating current, operates in a manner similar to a standard DC motor. Such a motor generally comprises a rotor formed of
20 permanent magnets and a stator winding used to establish a rotating magnetic field which interacts with the rotor magnets to cause rotation thereof.

It is an object of the present invention to provide an electric motor and method of manufacture which permits high power output and high
25 efficiency for comparatively small size and low rotational inertia.

Summary of the Invention

As used throughout this specification and claims, reference is made to magnets formed of one or more materials that display a "high permanent magnetism". Such magnets are deemed to be those which, when compared to
30 typical ferrite magnets as known in the art, display three or more times the magnetic flux density, and three or more times the coercive force, to give approximately ten times the total energy per unit volume.

In accordance with a first embodiment of the present invention there is disclosed an electric motor comprising:

35 a rotor having a cylindrical rotor body comprising a magnet of high permanent magnetism and shaft means configured to support said body for rotation;

a slotless armature core formed of a plurality of annular laminations; and

a slotless non-skewed armature winding positionable within said core and arranged about said rotor to provide an air gap between said
5 armature winding and said rotor, said armature winding comprising a plurality of phase windings energizable with multiphase electric currents to cause rotation of said rotor.

In accordance with another embodiment of the present invention there is disclosed a method of manufacturing an electric motor, said
10 method comprising the sequential steps of:

(a) providing a rotor comprising a cylindrical rotor body formed of a magnet of high permanent magnetism, and a shaft means configurable to support said body for rotation;

(b) providing a first layer of removable material about said rotor;

15 (c) coating said first layer with a second layer of non-removable material;

(d) forming over said non-removable material a slotless non-skewed armature winding comprising a plurality of phase windings;

(e) impregnating said armature winding with a non-removable
20 material;

(f) removing said removable material from between said armature winding and said rotor to leave said rotor freely rotatable within said winding; and

(g) inserting said winding and rotor into a slotless armature core
25 formed of a plurality of annular laminations.

In accordance with another embodiment of the present invention there is disclosed a method of manufacturing an electric motor, said method comprising the sequential steps of:

(a) providing a rotor comprising a cylindrical rotor body formed
30 of a magnet of high permanent magnetism, and a shaft means configurable to support said body for rotation;

(b) providing a cylindrical former and forming thereabout a slotless non-skewed armature winding comprising a plurality of phase windings;

35 (c) removing said former from said armature winding and inserting said armature winding into a slotless armature core formed of a plurality of annular laminations;

- (d) impregnating said winding with a non-removable material; and
- (e) inserting said rotor into said winding.

Generally, the high permanent magnetic materials are rare earth materials selected from the group comprising neodymium iron boron and samarium cobalt.

Typically, the rotor is magnetised to provide a two pole magnetic rotor. Four, six and eight pole configurations, for example, can also be used.

Generally, the removable material is a wax particularly a hydrocarbon wax such as paraffin which can be removed using cyclohexane or other organic solvent. Further, the non-removable material can be resin or other hardenable material, typically epoxy resin.

Also, advantageously, the armature winding has loop ends that extend over shaft portions that extend from the ends of the rotor body to leave a fully closed and captive rotor. Alternatively, the loop ends can be arranged at the ends of the armature core to create an open-open winding that permits removal of the rotor from within the winding from either end of the motor. A further alternative is to provide an open-closed winding where one set of loop ends enclose one end of the rotor body, and the remaining loop ends enclose the corresponding other end of the armature core..

The preferred embodiment achieves 96% efficiency at a full-load output of 150W with a 15°C temperature rise.

Brief Description of the Drawings

A number of preferred embodiments of the present invention will now be described with reference to the drawings in which:

Fig. 1 is a longitudinal cross-section of the preferred embodiment;

Fig. 2 is a cross-section along the line II-II of Fig. 1;

Fig. 3 is a schematic block diagram representation of a control system for the motor of Figs. 1 and 2;

Fig. 4 is a schematic representation of a switching controller useful as an alternative to the controller of Fig. 3;

Fig. 5 is a longitudinal cross-section of another embodiment.

Best and Other Modes of Carrying Out the Invention

Referring to Fig. 1, an electric motor 10 is shown which is configured for use as a hand-held motor suitable for applications such as sheep shears, drills, and the like. The motor 10 includes a rotor 11 formed of a cylindrical rotor body 17 and rotor ends 15 and 16.

The rotor body 17 comprises, and preferably is composed entirely of, a magnet of high permanent magnetism. Examples of such magnets are those formed of rare earth materials such as samarium cobalt and neodymium iron boron (NdFeB). Such materials typically display
5 approximately ten or more times the total energy per unit volume when compared to standard ferrite magnets. In this embodiment, the magnet is composed of 19%Nd, 80%Fe, and 1%B diametrically magnetised as a two-pole permanent magnet. A four-pole configuration can also be used.

The rotor ends 15 and 16 connect to respective ends of the rotor
10 body 17 to facilitate mounting and support for rotation by means of two shaft portions 29 and 30, respectively. The shaft portions 29,30 act as a drive shaft aligned with the longitudinal axis of the body 17. The ends 15 and 16 are manufactured of non-magnetic materials such as stainless steel. The ends 15 and 16 are fixed to the body 17 using a
15 number of pins 18.

Surrounding the rotor 11 is an air gap 14 of approximately 0.5 mm about which an armature winding 12 is formed. The armature winding 12 is a slotless, non-skewed, two pole winding having three phase windings having about 200 turns per phase of 4 strands of 0.18 mm copper wire. A
20 four-pole winding can also be used where appropriate. A skewed winding is not preferred due to various losses associated with such a winding.

It is apparent from Fig. 1 that, the winding 12 not only extends along the length of the rotor body 17, but has ends 28 that overlap from the rotor body 17 onto the shaft portions 29,30 of the rotor ends 15 and
25 16 to enclose the body 17. The overlapping ends 28 of the winding 12 minimise the lengths of the connections between the straight active lengths of the volume of copper used in the winding thereby reducing losses due to winding resistance.

Surrounding the winding 12 is a slotless armature core 13 formed of
30 a plurality of annular laminations. The core 13 can be formed of materials such as 3% silicon iron LYCORE 140, 0.35 mm thick per lamination, or preferably, a glassy metal such as METGLAS 260-S2, 0.02 mm thick. These lamination materials afford minimum losses and therefore high efficiency.

35 The core 13 is enclosed in a tubular case body 19 manufactured of non-magnetic stainless steel and two case ends 20 and 21 seal the case body 19.

Each of the case ends 21 and 20 include a bearing 26 and 27 (respectively) which supports the shaft portions 29,30 of the rotor ends 15 and 16 (respectively), to permit rotation thereof.

Inserted through the case end 21 and the bearing 26 into the rotor end 15 is an optical sensor shaft pin 25 which includes a cut out arranged to be detected by an optical sensor 24. The optical sensor 24 provides revolution feedback information to a motor controller (to be described). A socket end cap 22 encloses the case end 21 and provides a space for electrical connections to the winding 12 and to the optical sensor 24. A seven pin socket 23 is arranged at the end of the end cap 22 to provide for connection to the motor controller.

The shaft portion 30 extends beyond the case end 20 thus permitting connection of the motor to some implement. The motor 10 can be used in a variety of applications and can be scaled either up or down to provide motors of different size. Typically applications include sheep shearing motors, motors for robotic arms, surgical appliances, and the like.

Referring now to Fig. 2, the motor 10 is shown in cross-section in which it can be seen that the rotor body 17 is solid and has a radius r_m which in the preferred embodiment is typically between 7.2 and 8.8 mm and preferably about 8 mm. The air gap 14 is typically about 0.5 mm giving the radius r_1 equalling r_m plus 0.5 mm. The core 13 has an inner radius r_2 generally of between 13.6 and 14.4 mm, and preferably about 14 mm, and an external core radius r_0 of between 16 and 22 mm, and preferably about 18 mm.

The above described configuration provides the motor 10 with a full load performance at 150 watts output, 13,300 revolutions per minute and having 96% efficiency. The full load loss is 6.25W comprising a no-load loss of 3.45W and a winding loss of 2.80W. The temperature rise of the case body is 15°C above 24°C ambient.

The back-EMF generated by the motor 10 is very nearly a sinusoid. For maximum motor efficiency, sinusoidal voltages should be applied to the motor 10. Fig. 3 shows a motor controller 40 which provides a sinusoidal line to line voltage of about 147 volts at approximately 0.318 amps per phase.

The controller 40 comprises a phase locked loop 41 which receives a feed-back signal 65 from the optical shaft position sensor 24 described earlier. The phase locked loop (PLL) 41 also includes a further input from a phase adjust circuit 60. The output of the PLL 41 is a square

wave which is fed to a clock input of a digital, three phase sine wave generator 43. The clock frequency of the generator 43 is 18 times the desired frequency of the required sine wave.

5 A power-on-reset circuit 42 is provided so as to disable the output of the PLL 41 during that period immediately after power is applied. The output of the three phase sine wave generator 43 is input to a three phase level shifter and amplifier 44. The level shifter 44 outputs to a speed controller 48 via three balancing potentiometers 45, 46 and 47, one for each phase. A variable resistor 49 is provided for speed control.

10 The speed controller 48 outputs via low pass filters 51, 52 and 53 to power amplifiers 54, 55 and 56 respectively, one for each phase. A further low pass filter 50 is used to filter one of the outputs of the level shifter 44 to provide an input for the phase adjustment circuit 60. The low pass filter 50 corrects for a frequency dependent change in
15 phase between the signal input to the filters (51,52,53) and the signals output therefrom to the amplifiers (54,55,56). This difference, which can be about 2° up to a maximum signal frequency of 250 Hz, must be corrected otherwise the PLL 41 will operate incorrectly. The power amplifiers 54,55,56 are 150 watt MOSFET bipolar power amplifiers each of
20 which supply a respective step-up transformer 57, 58 and 59 which supply about 150 volts line-to-line to the motor 10. The step-up transformers are used in the ratio of 50:240. The controller 40 is configured for a drive frequency of 222 Hz corresponding to 13,300 revolutions per minute at full load.

25 Instead of supplying sinusoidal voltages to the motor 10, an alternative and less expensive controller 70 is shown in Fig. 4. The controller 70 can be used to supply six-step quasi-square-wave voltages to drive the motor 10, with a slight drop in motor efficiency, but much higher controller efficiency. In the controller 70, a power supply 71
30 converts A.C. mains 72 to a D.C. voltage 73. Solid state switches 75 in a three-phase bridge inverter 74 connect the motor phases of the winding 12 to the D.C. lines 73. The switches 75 are controlled by controlling integrated circuit 76 such as the MicroLinear ML4410 or Philips TDA5142 (or equivalent) which determines the switching times by sensing the motor
35 back-EMF via inputs 77. In this manner, only two of the three phase windings 12 are energized at any one time and the controlling IC 76 can examine the back-EMF of the remaining phase. A zero-crossing of the

back-EMF indicates the position of the rotor in a manner similar to the optical sensor 24 in the configuration of Fig. 3.

Control of motor speed can be achieved via a speed control feedback circuit 78 comparing a desired set speed 79 with a signal proportional to speed, produced by the IC 76. The feedback circuit 78 outputs a reference current 80 which is compared to a sensed version 81 of the actual D.C. current by the IC 76. The controlling IC 76 pulses the switches 75 on and off, varying the on duration to keep the actual current near the reference current 80.

Protection of the inverter 74 is provided by a current limit circuit in the controlling IC 76 and by a parallel inductor 83 and diode 84 combination in series with the D.C. supply 73.

The switching controller 70 finds application where efficiency of the motor 10 itself is less critical, but where the overall efficiency of the motor and controller is important, such as in battery powered applications.

The method of construction of the motor 10 can now be described. The rotor body 17 is constructed of solid VACODYM 400 NdFeB having a radius of 8.8 mm and a length of between 61 and 73 mm. The casing 19 is manufactured from non-magnetic stainless steel. The armature winding 12 is constructed as a non-skewed basket winding constructed by a lost wax process. A layer of removable material, such as wax, 0.5 mm thick (corresponding to the air gap 14) is formed on the rotor 11 enclosing the rotor body 17 and the rotor ends 15 and 16. The layer of wax is then covered with a thin layer of non-removable material such as epoxy resin, capable of absorbing stresses during the winding process. For example, five minute Araldite (registered trade mark) can be used. The winding 12 is then wound over the rotor 11, and radially compressed in a series of dies and vacuum impregnated with non-removable material such as epoxy resin (eg: Araldite LC191 plus Hardener LC226). The winding 12 is wound to be longitudinally aligned with the rotor 11 axis. The loop ends of the winding 12 are arranged to overlap the ends 15 and 16 of the rotor body 17, thereby reducing flux inconsistencies adjacent the magnetic poles of the rotor 11, and also conserving space. Once the winding is complete, the layer of wax is removed using a solvent such as cyclohexane. This leaves the rotor 11 captive within the winding 12. The rotor 11 is then magnetised.

The winding 12 and rotor 11 assembly is then inserted into the armature core 13 at the non-drive end (corresponding to the case end 21) using a sleeve of 0.8 mm thick mylar film (not illustrated). The mylar is slid in with the winding 12 and when trimmed is left in situ to form an insulation barrier between the winding 12 and earth (the casing 19).
5 The armature core 13, enclosing the winding 12 and rotor 11 was previously mounted within the casing 19 which is sealed using the case ends 20 and 21.

Turning now to Fig. 5, a motor 90 is shown which substantially
10 corresponds to the motor 10 of Figs. 1 and 2 with like components being identically numbered such that the corresponding descriptions apply. However, there are some differences.

Firstly, the optical sensor apparatus is omitted, thereby
15 permitting this embodiment to be directly used with the controller 70 of Fig. 4.

Also, the winding has been altered to show a winding 91 which does not overlap the ends 15,16 of the rotor body 17. In this embodiment, the length of the armature core 13 has been shortened by the removal of some laminations, so as to substantially align with the rotor body 17. The
20 shortening of the armature core 13 provides additional space within the casing 19 in which the loop ends 92 and 93 of the winding 91 can be positioned at the respective ends of the armature core 13 so that the rotor 11 is left free for removal from the motor 90, rather than being held captive as in the motor 10.

25 Because of this configuration, the winding 90 can either be wound around the rotor 11 (using a lost wax process as before), or around a removable former configured to match the dimensions of the rotor 11, air gap 14, and preferably the core 13.

In assembly, it is necessary to insert the winding 91 into the
30 casing 19 and compact the winding ends 92,93 around the armature core 13. Once this is done, the winding 91 can be filled with epoxy resin, and the rotor 11 then installed and magnetised.

It will be apparent from Figs. 1 and 5 that, where the shaft
portion 30 is appropriately sized, the armature winding can be configured
35 to overlap and enclose the rotor end 16 (as in Fig. 1) and leave the rotor end 15 open (as in Fig. 5) thereby minimizing magnetic flux inconsistencies and leakage, whilst permitting removal of the rotor 11. Such an open/closed winding configuration can be advantageous in terms of

obtaining a compromise between performance and manufacturing costs.

The motors 10,90 described above has several features which lead to a high power to volume ratio, a high peak torque capability, a linear current/torque relationship, low inertia, and a long thermal time

5 constant.

These features include a 2- or 4- pole solid cylindrical rare earth (e.g. NdFeB) permanent magnet rotor 11, a fixed air gap winding 12 (e.g. 3-phase) which is not skewed, a low loss stator core 13 (e.g. glassy metal), a low magnetic field in the case 19,20,21, a case 19,20,21 which
10 is a good thermal conductor, and a rotor position sensor 24 with electronic phase adjustment to control the phase angle between the rotor and the applied voltage or current.

A high power to volume ratio is achieved by obtaining a high torque to volume ratio at a high speed. This in turn is achieved by the
15 combination of all the features, provided the rotor radius, winding thickness and stator core thickness are optimised for minimum total loss at the required high speed.

The core thickness is also selected to achieve a low magnetic field in the case and hence low induced currents in the case, and low case
20 loss. Good thermal contact between the fixed winding, core, and case, and a thermally conducting case, provides a low temperature rise and contributes to the high torque to volume ratio.

The position sensor and electronic phase adjustment enables the current/torque ratio to be set to a minimum, thus reducing copper
25 losses. This adjustment, the solid permanent magnet rotor 11, and the air gap winding 12 lead to a linear current/torque relation, unaffected by tooth or core saturation, and to a high peak torque rating.

Industrial Applicability

The present invention is applicable to fields in which relatively
30 small, low inertia, high efficiency, high power electric motors are required. Such fields include sheep shearing motors, motors for robotic devices, and medical appliances.

The foregoing describes only a number of embodiments of the present invention, and modifications, obvious to those skilled in the art can be
35 made thereto without departing from the scope of the present invention.

CLAIMS:

1. An electric motor comprising:
 - a rotor having a cylindrical rotor body comprising a magnet of high permanent magnetism and shaft means configured to support said body for rotation;
 - a slotless armature core formed of a plurality of annular laminations; and
 - a slotless non-skewed armature winding positionable within said core and arranged about said rotor to provide an air gap between said armature winding and said rotor, said armature winding comprising a plurality of phase windings energizable with multiphase electric currents to cause rotation of said rotor.
2. A motor as claimed in claim 1, wherein said rotor body is composed of rare earth materials selected from the group consisting of neodymium iron boron and samarium cobalt.
3. A motor as claimed in claim 1, wherein respective ends of said armature core substantially align with said rotor body and said armature winding includes loop end portions arranged beyond and substantially enclosing said armature core ends.
4. A motor as claimed in claim 1, wherein said shaft means comprises two shaft portions which extend beyond respective ends of said rotor body and have diameters less than said body, and said armature winding comprises loop end portions arranged about said shaft portions to overlap and substantially enclose respective ends of said rotor body.
5. A motor as claimed in claim 1, wherein said armature winding is configured so that one end of said rotor body is unenclosed, thereby permitting removal of said rotor from therewithin.
6. A motor as claimed in claim 5, wherein the remaining end of said rotor body is overlapped and substantially enclosed by said armature winding.
7. A method of manufacturing an electric motor, said method comprising the sequential steps of:
 - (a) providing a rotor comprising a cylindrical rotor body formed of a magnet of high permanent magnetism, and a shaft means configurable to support said body for rotation;
 - (b) providing a first layer of removable material about said rotor;
 - (c) coating said first layer with a second layer of non-removable material;

(d) forming over said non-removable material a slotless non-skewed armature winding comprising a plurality of phase windings;

(e) impregnating said armature winding with a non-removable material;

(f) removing said removable material from between said armature winding and said rotor to leave said rotor freely rotatable within said winding; and

(g) inserting said winding and rotor into a slotless armature core formed of a plurality of annular laminations.

8. A method as claimed in claim 7, wherein said shaft means comprises at least one shaft portion which extends from a respective end of said rotor body and has a diameter less than said body, and step (d) comprises forming loops of said armature winding about said shaft portion to overlap and substantially enclose said respective end of said rotor body.

9. A method as claimed in claim 8, wherein both ends of said rotor body are overlapped and substantially enclosed by said armature winding so that said rotor is held captive within said armature winding.

10. A method as claimed in claim 7, wherein said removable material is wax.

11. A method as claimed in claim 7, wherein said removing is accomplished by a solvent.

12. A method as claimed in claim 11, wherein said solvent is cyclohexane.

13. A method of manufacturing an electric motor, said method comprising the sequential steps of:

(a) providing a rotor comprising a cylindrical rotor body formed of a magnet of high permanent magnetism, and a shaft means configurable to support said body for rotation;

(b) providing a cylindrical former and forming thereabout a slotless non-skewed armature winding comprising a plurality of phase windings;

(c) removing said former from said armature winding and inserting said armature winding into a slotless armature core formed of a plurality of annular laminations;

(d) impregnating said winding with a non-removable material; and

(e) inserting said rotor into said winding.

14. A method as claimed in claim 13, wherein step (c) further comprises:

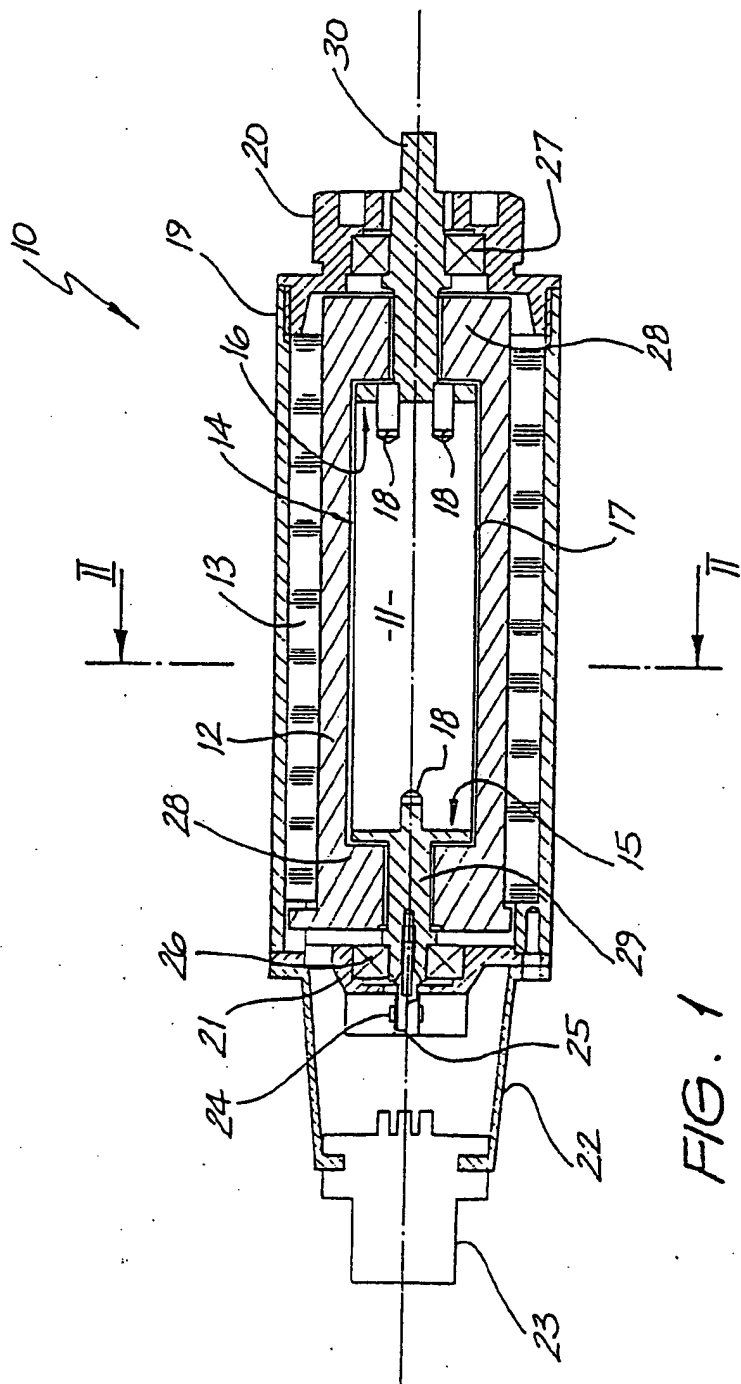
positioning loop ends of said armature winding adjacent at least one end of said armature core so as to permit insertion and removal of said rotor therewithin.

15. A method as claimed in claim 14, wherein both of said armature core are overlapped and substantially enclosed by said loop ends of said armature winding.

16. A method as claimed in claim 7 or 13, wherein said rotor body is composed of rare earth materials selected from the group consisting of neodymium iron boron and samarium cobalt.

17. A method as claimed in claim 7 or 13, wherein the non-removable material is a resin or like hardenable material.

1/5



2/5

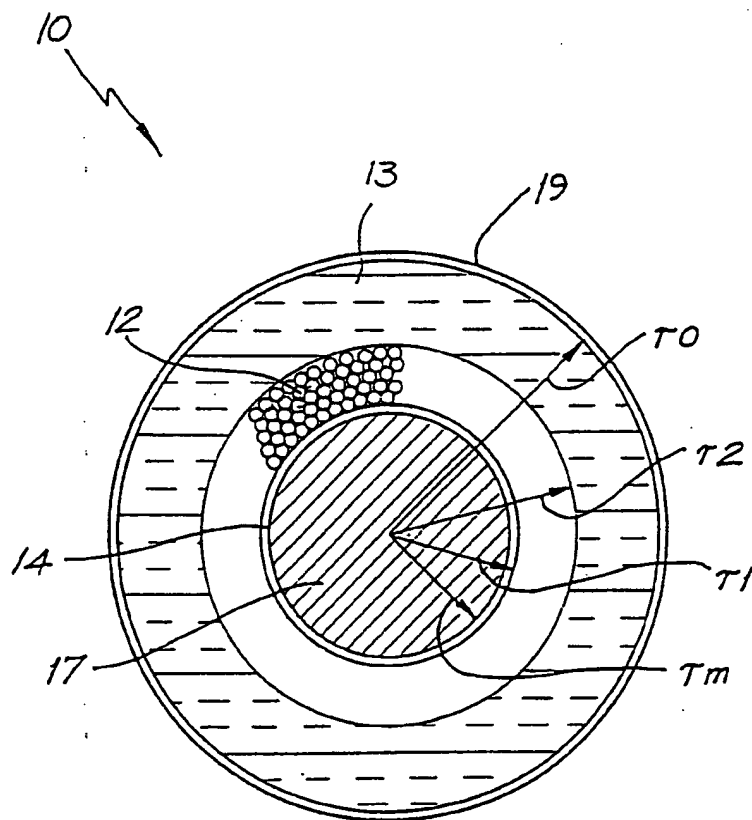
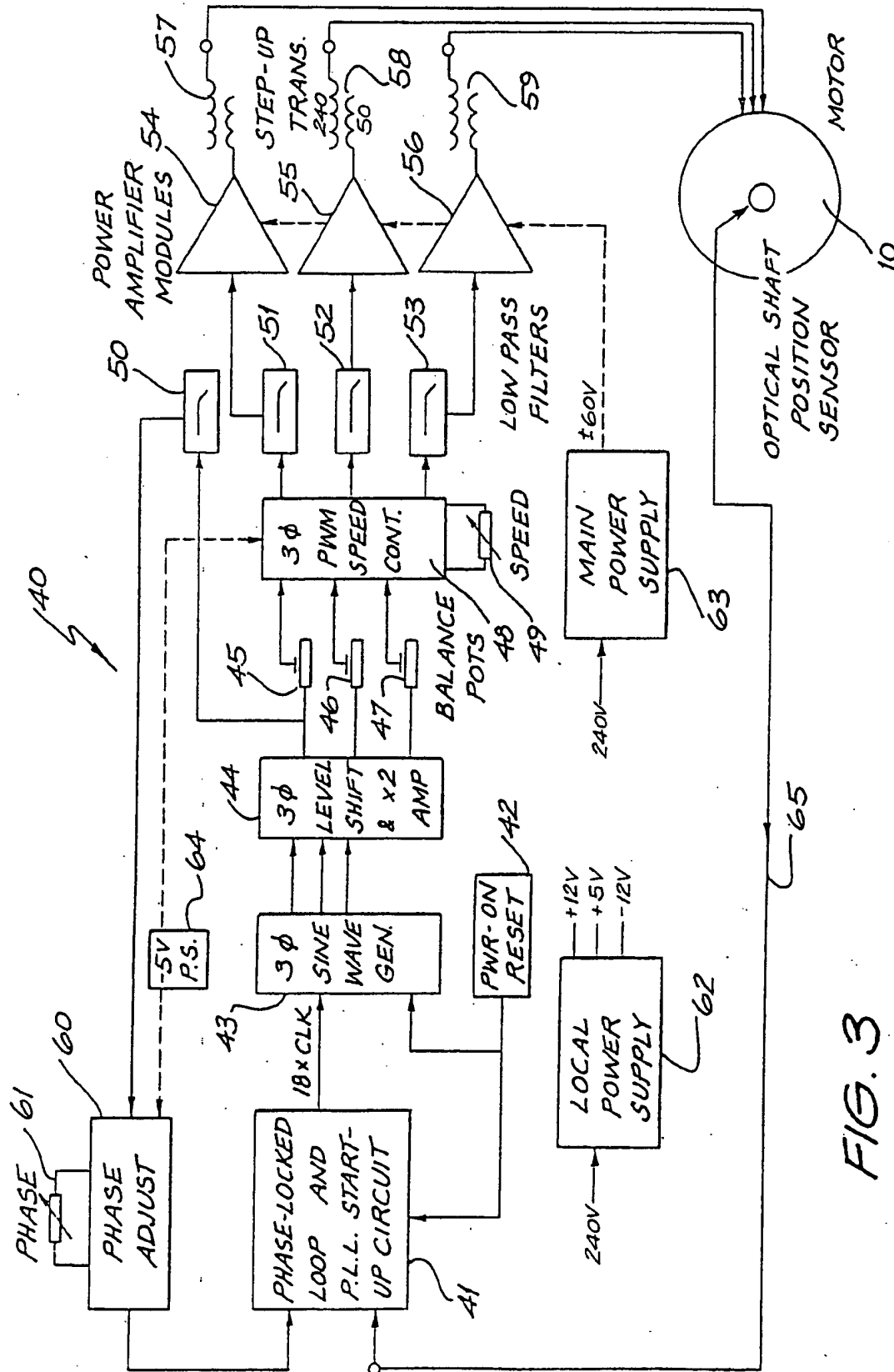


FIG. 2

3/5



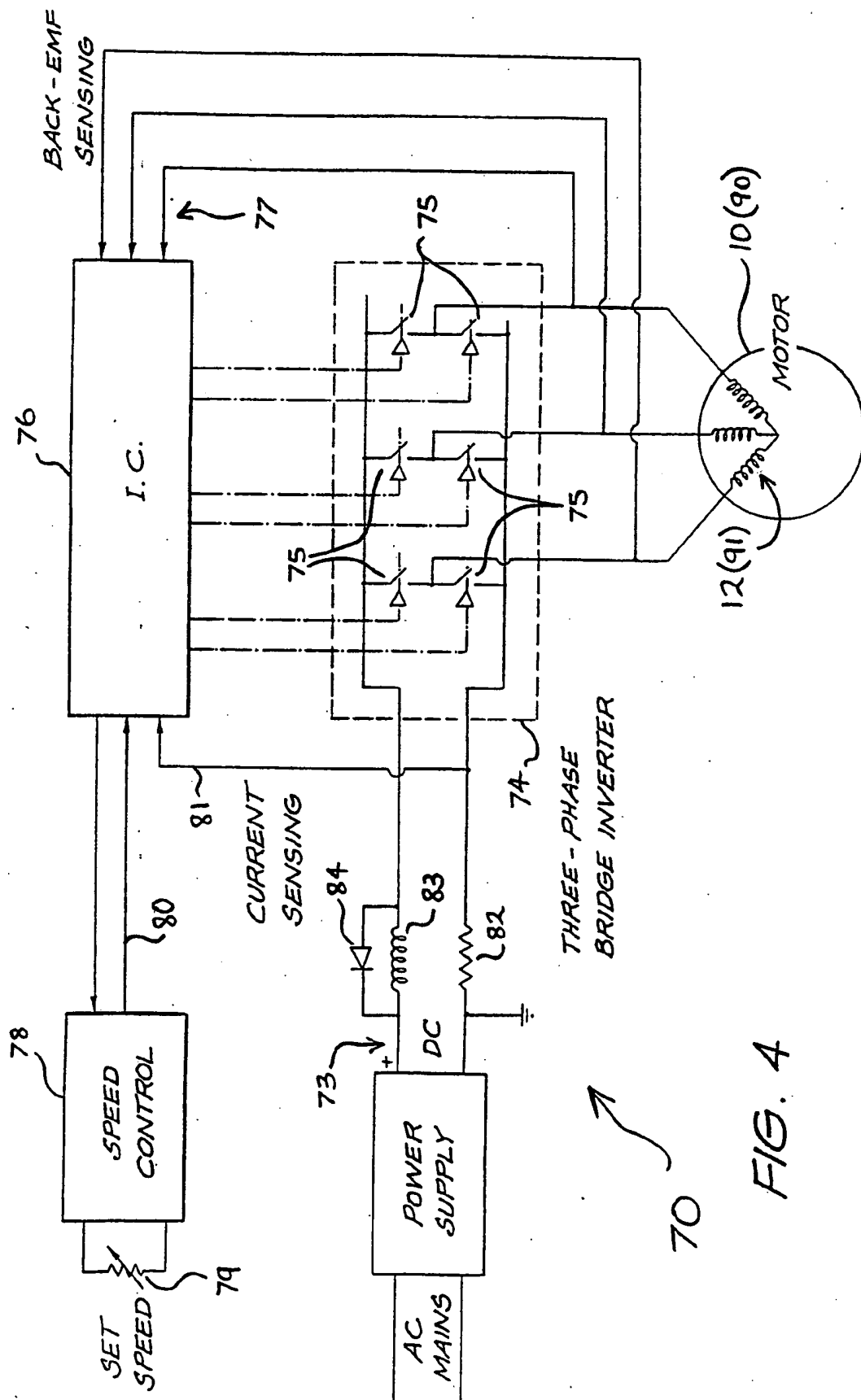


FIG. 4

5/5

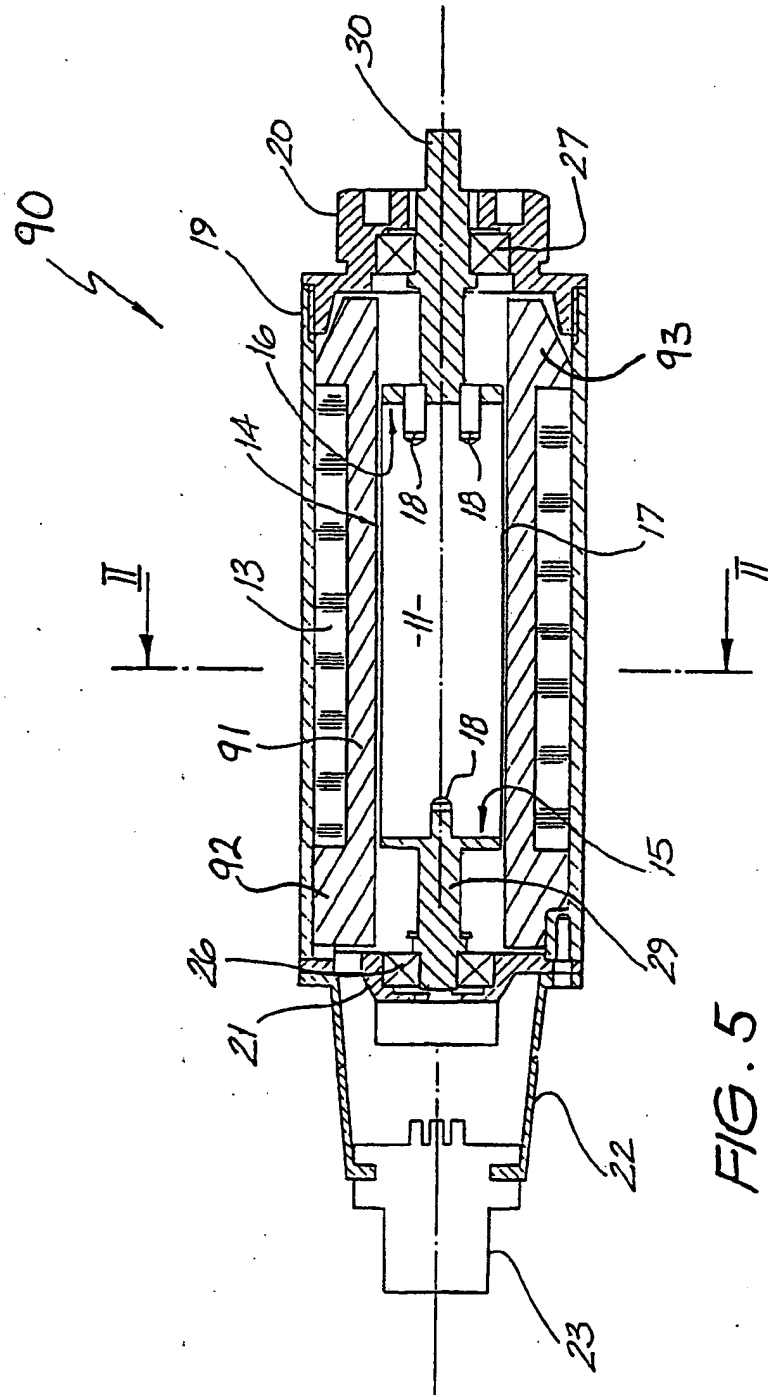
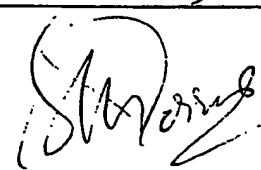


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 93/00274

A. CLASSIFICATION OF SUBJECT MATTER Int. Cl. ⁵ H02K 3/47				
According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED				
Minimum documentation searched (classification system followed by classification symbols) H02K 3/47, 3/04				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched AU:IPC as above				
Electronic data base consulted during the international search (name of data base, and where practicable, search terms used) DERWENT) H02K 15/02, 03, 08 AND KEYWORDS JAPIO) SLOTLISS OR CORELESS OR AIR GAP WINDING				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.		
X Y	EP,A,193929 (KOLLMORGEN) 10 September 1986 (10.09.86) column 1, line 50 to column 5, line 30, figures 1-47	1,2,5,13,14,16,17 3,4,6,15		
X Y	EP,A,282876 (KOLLMORGEN) 21 September 1988 (21.09.88) page 2 line 15 to page 4, line 8, figures 1-4,9-11	1,2,5,13,14,16,17 3,4,6,15		
X	WO,A,88/02192 (HHK INC) 24 March 1988 (24.03.88) page 8 line 11 to 37, figures 2,3,5,6	1,5		
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <input type="checkbox"/> Further documents are listed in the continuation of Box C. </div> <div style="width: 45%;"> <input type="checkbox"/> See patent family annex. </div> </div>				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top;"> * Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; vertical-align: top;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family </td> </tr> </table>			* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family			
Date of the actual completion of the international search 15 September 1993 (15.09.93)		Date of mailing of the international search report 21 SEP 1993 (21.09.93)		
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929		Authorized officer <div style="text-align: center;">  E. N. PERRIS Telephone No. (06) 2832167 </div>		

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 93/00274

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
P,X	EP,A,528347 (VEREINIGTE DRAHTWERKE) 24 February 1993 (24.02.93) entire document	1,5,6
P,X	WO,A,92/10024 (KINETRON) 11 June 1992 (11.06.92) page 3 lines 8-16, page 4 lines 3-5, 16-22 page 5 lines 15,16,25,26, figures 1,3,4	1,5
Y	DE,A,1039127 (SIEMENS-SCHUKERTWERKE) 18 September 1958 (18.09.58) figure 2	3
Y	DE,A,1023515 (TELEFONBAU UND NORMALZEIT) 30 January 1958 (30.01.58) figures 1-3	4

Information on patent family members

PCT/AU 93/00274

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
EP	193929	DE	3607648	GB	2172149	JP	61251466
		US	4679313	US	4868970	US	4954739
EP	282876	US	4868970	DE	3808190	GB	2203970
		JP	63 314153	GB	2172149	US	4679313
EP	528347	CA	2076412	CH	681840	JP	5199719
DE	1023515						
DE	1039127						
WO	9210024	NL	9002624				
WO	8802192	US	4733118	US	4937485		
END OF ANNEX							